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Pacific Gas and Electric Company
Natural Gas Transmission Pipeline Rupture and Fire
San Bruno, California
September 9, 2010

Accident Report

NTSB/PAR-11/01
PB2011-916501

National
Transportation
Safety Board

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PB2011-916501
Notation 8275C
Adopted August 30, 2011

Pipeline Accident Report

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National
Transportation
Safety Board

490 L'Enfant Plaza, S.W.
Washington, DC 20594

National Transportation Safety Board. 2011. ***Pacific Gas and Electric Company Natural Gas Transmission Pipeline Rupture and Fire, San Bruno, California, September 9, 2010*****. Pipeline Accident Report NTSB/PAR-11/01. Washington, DC.**

Abstract: On September 9, 2010, about 6:11 p.m. Pacific daylight time, a 30-inch-diameter segment of an intrastate natural gas transmission pipeline known as Line 132, owned and operated by the Pacific Gas and Electric Company, ruptured in a residential area in San Bruno, California. The rupture occurred at mile point 39.28 of Line 132, at the intersection of Earl Avenue and Glenview Drive. The rupture produced a crater about 72 feet long by 26 feet wide. The section of pipe that ruptured, which was about 28 feet long and weighed about 3,000 pounds, was found 100 feet south of the crater. The Pacific Gas and Electric Company estimated that 47.6 million standard cubic feet of natural gas was released. The released natural gas ignited, resulting in a fire that destroyed 38 homes and damaged 70. Eight people were killed, many were injured, and many more were evacuated from the area.

As a result of its investigation of this accident, the National Transportation Safety Board makes recommendations to the U.S. Secretary of Transportation, the Pipeline and Hazardous Materials Safety Administration, the governor of the state of California, the California Public Utilities Commission, the Pacific Gas and Electric Company, the American Gas Association, and the Interstate Natural Gas Association of America.

The National Transportation Safety Board is an independent Federal agency dedicated to promoting aviation, railroad, highway, marine, pipeline, and hazardous materials safety. Established in 1967, the agency is mandated by Congress through the Independent Safety Board Act of 1974 to investigate transportation accidents, determine the probable causes of the accidents, issue safety recommendations, study transportation safety issues, and evaluate the safety effectiveness of government agencies involved in transportation. The Safety Board makes public its actions and decisions through accident reports, safety studies, special investigation reports, safety recommendations, and statistical reviews.

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Acronyms and Abbreviations

AGA	American Gas Association
ANPRM	advance notice of proposed rulemaking
API	American Petroleum Institute
ASME	American Society of Mechanical Engineers
ASOS	Automated Surface Observing System
ASTM	American Society for Testing and Materials
ASV	automatic shutoff valve
CFR	*Code of Federal Regulations*
COF	consequence of failure
Consolidated Western	Consolidated Western Steel Corporation
CPUC	California Public Utilities Commission
DOT	U.S. Department of Transportation
DSAW	double submerged arc welded
ECDA	external corrosion direct assessment
ERW	electric resistance welded
GIS	geographic information system
GRI	Gas Research Institute
GSR	gas service representative
GTI	Gas Technology Institute
HCA	high consequence area
HV	Vickers hardness number
INGAA	Interstate Natural Gas Association of America
KSFO	San Francisco International Airport

ksi	1,000 pounds per square inch
LOF	likelihood of failure
MAOP	maximum allowable operating pressure
MOP	maximum operating pressure
MP	mile point
NPRM	notice of proposed rulemaking
NTSB	National Transportation Safety Board
PAPERS	Public Awareness Program Effectiveness Research Survey
PG&E	Pacific Gas and Electric Company
PHMSA	Pipeline and Hazardous Materials Safety Administration
PLC	programmable logic controller
psi	pounds per square inch
psig	pounds per square inch, gauge
RCV	remote control valve
RMP	risk management procedure
RSPA	Research and Special Programs Administration
SBFD	San Bruno Fire Department
SCADA	supervisory control and data acquisition
SMLS	seamless
SMYS	specified minimum yield strength
the Corps	U.S. Army Corps of Engineers
UPS	uninterruptible power supply

Executive Summary

On September 9, 2010, about 6:11 p.m. Pacific daylight time, a 30-inch-diameter segment of an intrastate natural gas transmission pipeline known as Line 132, owned and operated by the Pacific Gas and Electric Company (PG&E), ruptured in a residential area in San Bruno, California. The rupture occurred at mile point 39.28 of Line 132, at the intersection of Earl Avenue and Glenview Drive. The rupture produced a crater about 72 feet long by 26 feet wide. The section of pipe that ruptured, which was about 28 feet long and weighed about 3,000 pounds, was found 100 feet south of the crater. PG&E estimated that 47.6 million standard cubic feet of natural gas was released. The released natural gas ignited, resulting in a fire that destroyed 38 homes and damaged 70. Eight people were killed, many were injured, and many more were evacuated from the area.

Investigation Synopsis

The National Transportation Safety Board's investigation found that the rupture of Line 132 was caused by a fracture that originated in the partially welded longitudinal seam of one of six short pipe sections, which are known in the industry as "pups." The fabrication of five of the pups in 1956 would not have met generally accepted industry quality control and welding standards then in effect, indicating that those standards were either overlooked or ignored. The weld defect in the failed pup would have been visible when it was installed. The investigation also determined that a sewer line installation in 2008 near the rupture did not damage the defective pipe.

The rupture occurred at 6:11 p.m.; almost immediately, the escaping gas from the ruptured pipe ignited and created an inferno. The first 911 call was received within seconds. Officers from the San Bruno Police Department arrived on scene about 6:12 p.m. Firefighters at the San Bruno Fire Department heard and saw the explosion from their station, which was about 300 yards from the rupture site. Firefighters were on scene about 6:13 p.m. More than 900 emergency responders from the city of San Bruno and surrounding jurisdictions executed a coordinated emergency response, which included defensive operations, search and evacuation, and medical operations. Once the flow of natural gas was interrupted, firefighting operations continued for 2 days. Hence, the emergency response by the city of San Bruno was prompt and appropriate.

However, PG&E took 95 minutes to stop the flow of gas and to isolate the rupture site—a response time that was excessively long and contributed to the extent and severity of property damage and increased the life-threatening risks to the residents and emergency responders. The National Transportation Safety Board found that PG&E lacks a detailed and comprehensive procedure for responding to large-scale emergencies such as a transmission pipeline break, including a defined command structure that clearly assigns a single point of leadership and allocates specific duties to supervisory control and data acquisition staff and other involved employees. PG&E's supervisory control and data acquisition system limitations caused delays in pinpointing the location of the break. The use of either automatic shutoff valves or remote control valves would have reduced the amount of time taken to stop the flow of gas.

PG&E's pipeline integrity management program, which should have ensured the safety of the system, was deficient and ineffective because it—

- Was based on incomplete and inaccurate pipeline information.
- Did not consider the design and materials contribution to the risk of a pipeline failure.
- Failed to consider the presence of previously identified welded seam cracks as part of its risk assessment.
- Resulted in the selection of an examination method that could not detect welded seam defects.
- Led to internal assessments of the program that were superficial and resulted in no improvements.

Several deficiencies revealed by the National Transportation Safety Board investigation, such as PG&E's poor quality control during the pipe installation and inadequate emergency response, were factors in the 2008 explosion of a PG&E gas pipeline in Rancho Cordova, California. (See *Explosion, Release, and Ignition of Natural Gas, Rancho Cordova, California, December 24, 2008*, Pipeline Accident Brief NTSB/PAB-10/01 [Washington, DC: National Transportation Safety Board, 2010].) This 2008 accident involved the inappropriate installation of a pipe that was not intended for operational use and did not meet applicable pipe specifications. PG&E's response to that event was inadequate; PG&E initially dispatched an unqualified person to the emergency, causing an unnecessary delay in dispatching a properly trained and equipped technician. Some of these deficiencies were also factors in the 1981 PG&E gas pipeline leak in San Francisco, which involved inaccurate record-keeping, the dispatch of first responders who were not trained or equipped to close valves, and unacceptable delays in shutting down the pipeline. (See *Pacific Gas & Electric Company Natural Gas Pipeline Puncture, San Francisco, California, August 25, 1981*, Pipeline Accident Report NTSB/PAR-82/01 [Washington, DC: National Transportation Safety Board, 1982].) The National Transportation Safety Board concluded that PG&E's multiple, recurring deficiencies are evidence of a systemic problem.

The investigation also determined that the California Public Utilities Commission, the pipeline safety regulator within the state of California, failed to detect the inadequacies in PG&E's integrity management program and that the Pipeline and Hazardous Materials Safety Administration integrity management inspection protocols need improvement. Because the Pipeline and Hazardous Materials Safety Administration has not incorporated the use of effective and meaningful metrics as part of its guidance for performance-based management pipeline safety programs, its oversight of state public utility commissions regulating gas transmission and hazardous liquid pipelines could be improved. Without effective and meaningful metrics in performance-based pipeline safety management programs, neither PG&E nor the California Public Utilities Commission was able to effectively evaluate or assess PG&E's pipeline system.

Probable Cause

The National Transportation Safety Board determines that the probable cause of the accident was the Pacific Gas and Electric Company's (PG&E) (1) inadequate quality assurance and quality control in 1956 during its Line 132 relocation project, which allowed the installation of a substandard and poorly welded pipe section with a visible seam weld flaw that, over time grew to a critical size, causing the pipeline to rupture during a pressure increase stemming from poorly planned electrical work at the Milpitas Terminal; and (2) inadequate pipeline integrity management program, which failed to detect and repair or remove the defective pipe section.

Contributing to the accident were the California Public Utilities Commission's (CPUC) and the U.S. Department of Transportation's exemptions of existing pipelines from the regulatory requirement for pressure testing, which likely would have detected the installation defects. Also contributing to the accident was the CPUC's failure to detect the inadequacies of PG&E's pipeline integrity management program.

Contributing to the severity of the accident were the lack of either automatic shutoff valves or remote control valves on the line and PG&E's flawed emergency response procedures and delay in isolating the rupture to stop the flow of gas.

Recommendations

The National Transportation Safety Board makes new recommendations to the U.S. Secretary of Transportation, the Pipeline and Hazardous Materials Safety Administration, the governor of the state of California, the California Public Utilities Commission, the Pacific Gas and Electric Company, the American Gas Association, and the Interstate Natural Gas Association of America.

The National Transportation Safety Board previously issued recommendations to the Pipeline and Hazardous Materials Safety Administration, the California Public Utilities Commission, and the Pacific Gas and Electric Company as a result of this accident.

1. Factual Information

1.1 Accident Narrative

On September 9, 2010, about 6:11 p.m. Pacific daylight time,[1] a 30-inch-diameter segment of an intrastate natural gas transmission[2] pipeline known as Line 132, owned and operated by the Pacific Gas and Electric Company (PG&E), ruptured in a residential area in San Bruno, California. The rupture occurred at mile point (MP) 39.28 of Line 132,[3] at the intersection of Earl Avenue and Glenview Drive. The rupture produced a crater about 72 feet long by 26 feet wide. (See figure 1.) The section of pipe that ruptured, which was about 28 feet long, and weighed about 3,000 pounds, was found 100 feet south of the crater. (See figure 2.) PG&E estimated that 47.6 million standard cubic feet of natural gas was released. The released natural gas ignited, resulting in a fire that destroyed 38 homes and damaged 70. (See figure 3.) Eight people were killed, many were injured, and many more were evacuated from the area.

The ruptured pipe segment was installed in 1956. According to PG&E records (which were later found to be incorrect), the ruptured segment was constructed from 30-inch-diameter, seamless American Petroleum Institute (API) 5L[4] grade X42[5] steel pipe with a 0.375-inch wall thickness. The maximum allowable operating pressure (MAOP[6]) for Line 132 was 400 pounds per square inch, gauge (psig). The PG&E specified maximum operating pressure (MOP[7]) was 375 psig.

[1] All times in this report are Pacific daylight time unless otherwise specified.

[2] A transmission line is defined as a pipeline, other than a gathering line, that (1) transports gas from a gathering line or storage facility to a distribution center, storage facility, or large-volume customer that is not downstream from a distribution center; (2) operates at a hoop stress of 20 percent or more of specific minimum yield strength (SMYS); or (3) transports gas within a storage field.

[3] MPs are measured along the length of the pipeline relative to the distance from the Milpitas Terminal, where Line 132 originates, which is designated as MP zero.

[4] The API develops industry-based consensus standards that support oil and gas production and distribution. API 5L is a specification for line pipe.

[5] This signifies that the pipe has a SMYS of 42,000 pounds per square inch (psi). Yield strength is a measure of the pipe's material strength and indicates the stress level at which the material will exhibit permanent deformation. Although yield strength is expressed in psi, this value is not equivalent to a pipe's internal pressure.

[6] MAOP is defined by the Pipeline and Hazardous Materials Safety Administration (PHMSA) as the maximum pressure at which a pipeline or segment of a pipeline may be operated under Title 49 *Code of Federal Regulations* (CFR) Part 192. (Part 192 contains the minimum Federal safety standards for the transportation of natural gas by pipeline.)

[7] MOP is an operating limit defined by PG&E. As explained by PG&E, sometimes a line's MOP equals the MAOP. But when a line is crosstied to (open to) a line with a lower MAOP, the higher rated line is limited by the MAOP of the lower rated line. In the case of Line 132, when it was open to Line 109 (which had a MAOP of 375 psig), as it was at the time of the accident, the MOP of Line 132 was 375 psig.

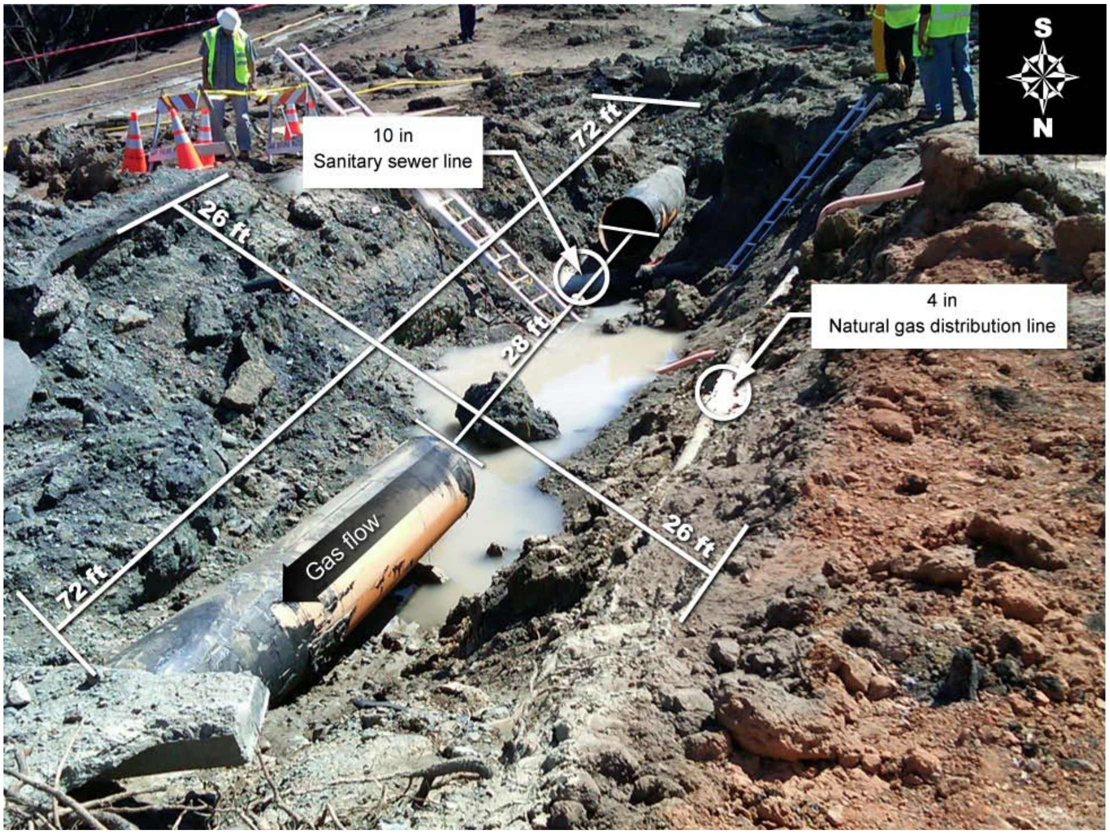

Figure 1. Picture of crater and ruptured pipeline.

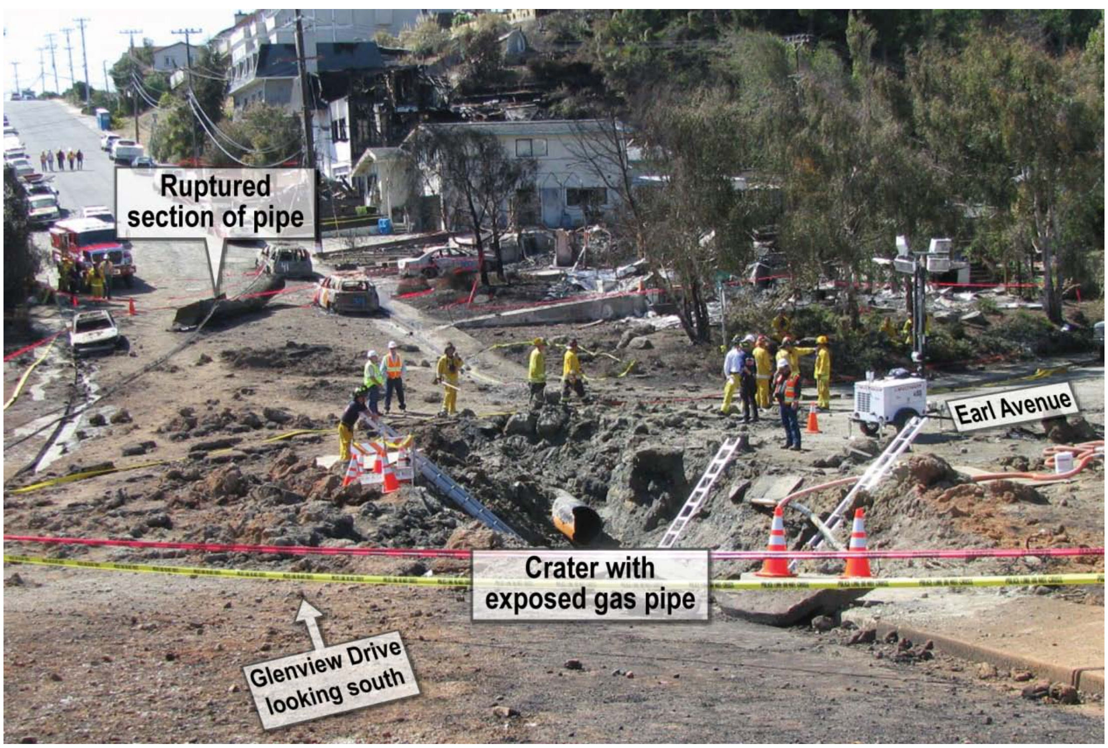

Figure 2. Picture of ejected pipe section.

Figure 3. Aerial view of fire.

1.1.1 Preaccident Events

During the hours leading up to the accident, three PG&E employees and one contractor were working on an electrical distribution system as part of the replacement of the uninterruptible power supply (UPS[8]) at the Milpitas Terminal, where Line 132 originates. (See figure 4.) The electric work had been approved by a PG&E work clearance[9] form, which was submitted to PG&E's gas control center (referred to in this report as the SCADA[10] center) on August 19, 2010, and approved on August 27, 2010.

[8] A UPS is an electrical apparatus that provides backup power.

[9] A work clearance is a procedure used by PG&E to notify the supervisory control and data acquisition (SCADA) center of work that may affect gas flow, gas quality, or SCADA monitoring. For more information about the work clearance process, see section 1.9.1.2, "Work Clearance Procedures."

[10] PG&E used a computer-based SCADA system to remotely monitor and control the movement of gas through its pipelines. SCADA operators located at the SCADA center in San Francisco monitor operating parameters such as flow rates, pressures, equipment status, control valve positions, and alarms indicating abnormal conditions. (For more information, see section 1.9.1, "SCADA System Operations.")

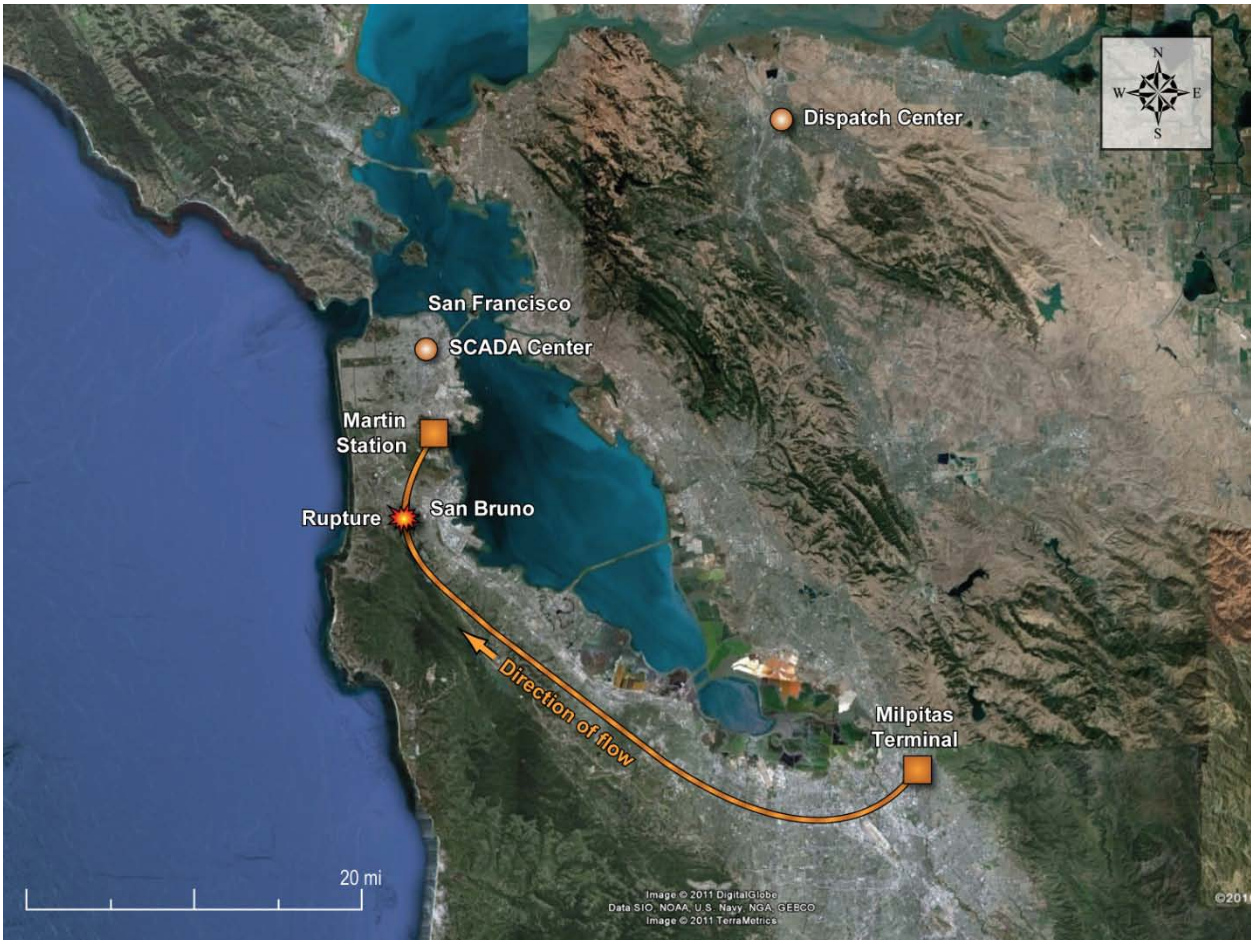

Figure 4. Overview of Line 132.

The work on September 9, 2010, was the continuation of a larger project to temporarily transfer electrical loads from an existing UPS distribution panel onto individual smaller UPS devices.[11] The intent of this operation was to complete the removal of all loads from the existing UPS distribution panel so it could be removed from service and replaced. Future work included replacing the UPS and transferring each load from the small, temporary UPSs back onto a new UPS.

On the evening of September 9, 2010, one SCADA operator (operator D) became the primary point of contact for workers at the Milpitas Terminal, but at various times all five of the SCADA staff answered telephone calls and handled alarms relating to events at the Milpitas Terminal. The SCADA operators sat together in the SCADA center and communicated frequently throughout the evening about the work. (It should also be noted that the San Francisco SCADA operations were scheduled to move during the next shift to an alternate SCADA facility in Brentwood, California, as part of a regular exercise. Some of the SCADA operators scheduled to work the night shift, who had reported to the Brentwood location, were monitoring the lines and were communicating by telephone with the day shift SCADA staff in San Francisco.

[11] The smaller UPS devices serve a single component on a circuit.

However, after the rupture of Line 132, the exercise at the Brentwood facility was cancelled, and the staff at Brentwood reported to the San Francisco facility.)

1.1.2 Events Leading Up to Rupture

At 2:46 p.m. (about 3.5 hours before the rupture), a gas control technician at the Milpitas Terminal (hereafter referred to as the Milpitas technician) spoke with SCADA operator A in San Francisco to initiate the work clearance for the planned UPS work. At 3:36 p.m., the Milpitas technician called the SCADA center and spoke with SCADA operator B to find out whether the valves on two of the incoming lines would close upon losing power. Operator B confirmed that they would fail closed. The Milpitas technician then informed operator B that he would lock the valves open.

Before performing the transfer of equipment that powered instrumentation and provided SCADA data to the SCADA center, the workers at the Milpitas Terminal called the supervisor of SCADA and controls to discuss the impacts of the work. He advised them to put the regulating control valves[12] in manual control to prevent the valves from operating.

As the electrical work progressed, the Milpitas technician called the SCADA center to alert them each time work was about to begin that would affect SCADA data. In keeping with this practice, at 4:03 p.m., the Milpitas technician alerted SCADA operator C that the installation of one of the smaller UPSs was about to begin. The Milpitas technician stated that he was going to put the regulating valves in manual control at the regulating valve controllers and return them to automatic after the transfer was complete. During this portion of the electrical work, beginning at 4:18 p.m., the SCADA center lost SCADA data for pressures, flows, and valve positions at the Milpitas Terminal. SCADA operator B called the Milpitas Terminal at 4:32 p.m., asking "What's going on?" in reference to the extended loss of SCADA data. During that phone call, the workers at the Milpitas Terminal were in the process of restoring power and SCADA data. At 4:38 p.m., the Milpitas technician contacted the SCADA center to verify the SCADA data had returned to normal. At the completion of this portion of the electrical work, the regulating valve controllers were returned to automatic control.

Following the transfer of critical loads from the UPS panel, workers at the Milpitas Terminal began to remove power from an unidentified breaker. During that work, the workers opened a circuit that resulted in a local control panel unexpectedly losing power. (See figure 5.) Rather than reenergizing the circuit, the workers pulled drawings and began investigating how to power the local control panel from an alternate source. One of the technicians stated in a postaccident interview that while measuring electrical currents with a clamp-on amp meter, the workers noticed some of the displays at the local control panel went blank. Subsequent troubleshooting showed this to be the result of erratic output voltages from two redundant 24-volt d.c. power supplies (power supplies A and B on figures 6a and 6b). These

[12] The regulating valves operate as the primary means of pressure control through the Milpitas Terminal. They are full port valves with electric actuators governed by controllers. Pressure sensors control the position of the valves from fully open to fully closed or in between to maintain a downstream pressure or be given a percent open by the gas system operator.

erratic voltages to pressure transmitters resulted in an erroneous low pressure signal to regulating valve controllers, causing them to command the regulating valves to a fully open position. (See figure 7.) Until then, the regulating valves on all incoming lines except Line 300B had been closed. When the valves opened fully, the monitor valves, whose purpose is to protect against accidental overpressure, became the only means of pressure control. The erratic voltages from the 24-volt power supplies also affected valve position sensors, generating erroneous signals to the SCADA center.

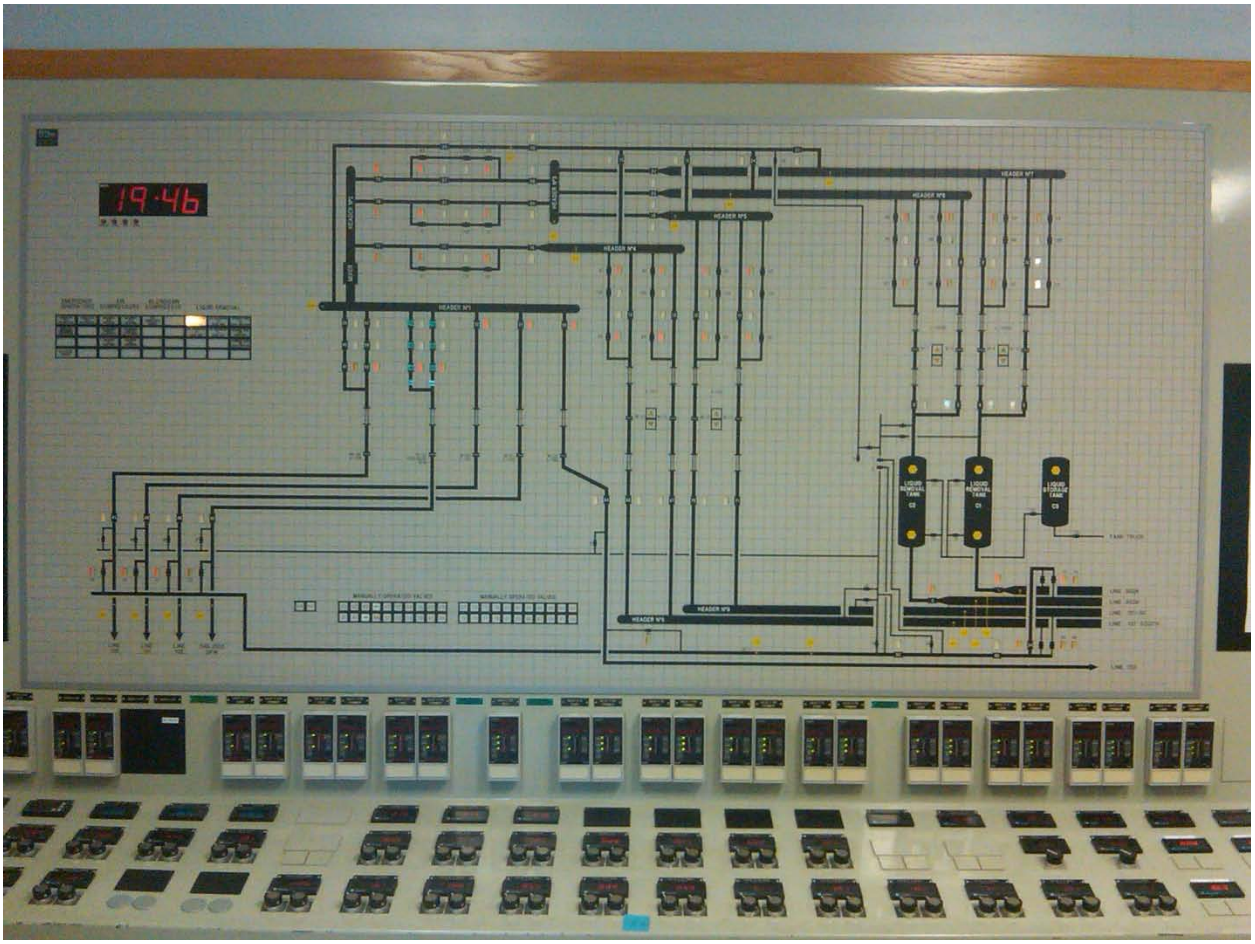

Figure 5. Picture of local control panel.

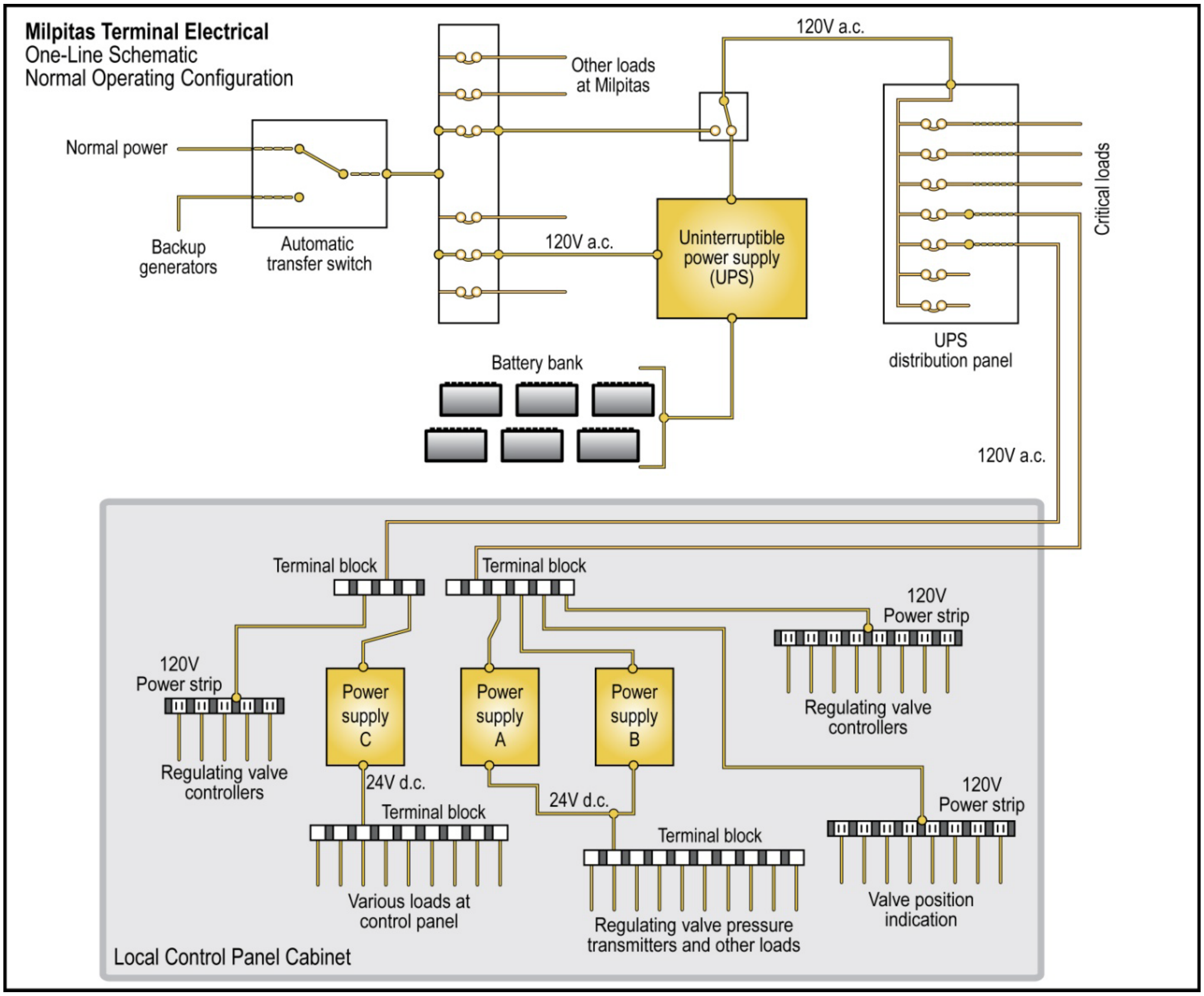

Figure 6a. Normal electrical configuration at the Milpitas Terminal.